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**Citation for published version:**

Biro, A 2017, 'Effect of ageing on the ownership of durable goods', *Scottish Journal of Political Economy*, vol. 64, no. 5, pp. 501-529. <https://doi.org/10.1111/sjpe.12131>

**Digital Object Identifier (DOI):**

[10.1111/sjpe.12131](https://doi.org/10.1111/sjpe.12131)

**Link:**

[Link to publication record in Edinburgh Research Explorer](#)

**Document Version:**

Peer reviewed version

**Published In:**

Scottish Journal of Political Economy

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# Effect of ageing on the ownership of durable goods

Accepted version of the article with DOI 10.1111/sjpe.12131 in the Scottish Journal of Political

Economy

Anikó Bíró\*

May 4, 2017

## Abstract

I analyse how ageing affects the demand for non-housing durable goods. Based on the English Longitudinal Study of Ageing, individual characteristics, cohort and time effects can explain most of the age variation in the ownership and purchase of durable goods. A life-cycle model is derived to capture the complex relation between ageing and the demand for non-housing durable goods. Decreasing survival probability, deteriorating health and changing preferences are jointly reflected in the age gradient of demand. Simulations indicate that higher chances of survival increase the ownership ratio of the durable items.

**Keywords:** consumer durables, life-cycle model, ownership, subjective survival probability

**JEL codes:** D11, D12, J14

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\*The University of Edinburgh, Corvinus University of Budapest (funded by the Postdoctoral Fellowship Program of the Hungarian Academy of Sciences). E-mail: aniko.biro@ed.ac.uk.

# 1 Introduction

I analyse the effect of ageing on the demand for non-housing durable goods (henceforth durable goods). One would expect that as people get older, they invest less in durable goods since they have shorter remaining lifetime to enjoy the use value of these goods. However, this relation is not trivial; the shorter remaining lifetime might make the investment in durable goods less desirable. However, the utility derived from some durable goods might increase with age due to longer hours spent at home. Empirical evidence indeed suggests that the demand for some durable goods (e.g. televisions) is increasing with age. Unlike in the case of housing, decisions on non-housing durable good ownership is made regularly, but unlike in the case of non-durable consumption, the decision still has consequences for future utilities derived from the good. Thus, the trade-off implied by higher use value versus shorter remaining lifetime is more relevant in the case of non-housing durable goods than housing durable goods or non-durable consumption. In addition, increasing longevity can have a different effect on the demand for different types of durable goods. I discuss these differences in details in this paper.

With increasing expected lifetime, the expenditures of older people have a rising share in aggregate household expenditures. According to UK statistics (Office for National Statistics (2010)), total household expenditures decrease with age above age 30, but the share of expenditures on household goods and services within total expenditures increases with age. The aggregate share of these expenditures was 6.4% in 2008, but higher for older age groups: 7.4% at age 65-74 and 8.1% at age 75 and above. Focusing on ownership, my aims in this paper are to understand better the age pattern of the ownership of durable goods at age 50 and

above, and to investigate how increasing longevity affects ownership. The results extend our knowledge not only to the demand for non-housing durable goods, but also to a study of the welfare of people at older ages.

I will provide descriptive evidence for the age pattern of durable ownership using the English Longitudinal Study of Ageing. This survey hence presents rich information on the ownership and purchases of and expenditures on durable goods. The age coverage of the sample (age 50 and above) makes it possible to focus on the effects of ageing. Although some of the analysed goods have very high (above 80%) ownership rates, the age patterns of ownership and purchases still differ across different categories of durable goods. In particular, there are striking differences in the age patterns of ownership of goods that are leisure complements and require little technical knowledge (e.g. televisions) and goods whose use require good mental and physical health (e.g. computers).

To understand the complex relations between ageing and the demand for durables, theoretical analysis and simulations are needed. Decreasing survival probabilities, declining health and changing preferences are all different aspects of the ageing process, influencing the demand for durables. I develop a life-cycle model which takes into account that durable good ownership is a binary choice. I allow ownership to change every 10 years. The model is based on an uncertain lifetime, taking into account interactions between durable good ownership and non-durable consumption. Hence, it allows the utility weight of durable goods to depend on health and age.

Simulation exercises are then applied to illustrate the model's results. When possible, the simulations are based on standard parameter values from the literature. I will analyse the influence of discounting, health, and of changing longevity on two types of durable goods;

namely, televisions and computers. In the Appendix, I will also look at the effects of bequest motives and retirement.

The results indicate that, conditional on the constant annual income (hence spending power) of elderly people, with population ageing we should expect to see increasing demand for non-housing durable goods. This is partly due to increasing longevity and partly due to the higher utility attached to some types of durable items at older ages. Notably, such items are goods that are leisure complements, where the use of which does not require good mental or physical health.

The rest of the paper is structured as follows. I review the related literature in section 2. Section 3 presents the data used in the empirical analysis, followed by empirical evidence of the effects of ageing in section 4. The life-cycle model and simulation results are presented in section 5. Section 6 then concludes the study.

## **2 Related literature**

Compared to the rich literature available on the consumption of non-durable goods over the life-cycle and on housing demand, the literature on the demand for non-housing durable goods is relatively meagre, despite their non-negligible share within total household expenditures. The current paper helps fill this gap, focusing on how the ageing of populations affects the demand for non-housing durable goods.

The papers with the closest relation to the current analysis are the ones that look at consumption; in particular, durable goods demand over the life-cycle. Many of the seminal papers that present life-cycle models do not investigate the demand for durable goods. The

ones that look at the demand for durable goods generally focus on expenditures, whereas my focus is on ownership. While expenditures are important for the household budget, it is ownership and the consumption service flow following from it that provide utility. In this sense, my analysis complements the existing literature. For example, apart from performing a robustness check, Gourinchas and Parker (2002) make no distinction between durables and non-durables in their analysis of consumption over the life-cycle. Yang (2009), although analysing the different age pattern of housing and non-housing consumption, does not analyse separately the consumption of non-housing durable goods. Based on U.S. data, Fernandez-Villaverde and Krueger (2007) document that both durable and non-durable expenditures are humped-shaped over the life-cycle. A similar descriptive analysis is provided by Alessie and de Ree (2009) based on Dutch data, which also shows a humped-shaped pattern of durable consumption.

Fernandez-Villaverde and Krueger (2011) present a dynamic general equilibrium model to explain the life-cycle pattern of durable and non-durable consumption. In their model, durables provide consumption services and act as collateral for loans. In this paper I present a simpler model than Fernandez-Villaverde and Krueger (2011) in the sense that I only consider the utility maximisation problem of the individual (household). However, I model the individual's problem in more detail, bringing it closer to real life problems. Among other elements, I allow health to enter the utility function and to affect the marginal utility of consumption and survival probability at the same time. I also include bequest motives in the model. To the best of my knowledge, the paper by Browning et al. (2014) is the only one to analyse the demand for durable goods based on British data. Based on the British Household Panel Survey, they find that the demand for consumer electronics rises with age,

while the demand for household appliances is flat. Using an alternative data source and different empirical strategy, my empirical findings on the age pattern of durable goods demand are somewhat different, as discussed in section 4. Moreover, the life-cycle model and the following simulations I present and, in particular, my focus on durable good ownership and its relation to survival probabilities are also novel in the literature.

Apart from the papers cited above, some other strands of the literature also investigate certain aspects of the demand for durable goods. Although related in topic, these papers have less direct relevance for the analysis presented in this paper.

The "early" papers from the 1960s and 70s (Wu (1965), Hamburger (1967), Juster and Wachtel (1974), among others) provide the first models of demand for household durable goods, with a focus on durable good expenditures. While my paper contributes to the understanding of the microeconomic aspect of the demand for durable goods, another set of related studies consists of papers that derive macroeconomic models with durable goods (Ogaki and Reinhart (1998), Lastrapes and Potts (2006), Monacelli (2009), among others). Other papers look at the dynamics of consumer demand for narrow categories of durable goods. For example, Melnikov (2013) analyses the U.S. computer printer market, while Gowrisankaran and Rysman (2012) investigate demand in the digital camcorder market. In this paper, I focus on age patterns in the demand for certain groups of durable goods, but I do not aim to provide a market analysis or to investigate the choice between differentiated products within a certain category of durables.

### 3 Data

The empirical analysis is based on the English Longitudinal Study of Ageing (ELSA), waves 1-6.<sup>1</sup> The ELSA is a biannual panel data set, covering a representative sample of the English population aged 50 and over and their spouses. The first survey wave was conducted in 2002-2003. Apart from providing information on a rich set of socioeconomic and demographic characteristics, the ELSA also includes variables related to the ownership and purchase of various durable goods. Here I exclude individuals living in institutions (0.4% of the sample) and those who do not own the property they live at (18% of the sample). The only reason why I analyse homeowners is because in rented properties some durable items (especially the washing machine) might be provided with the property. Thus, the lack of durable ownership might in fact reflect the lack of housing ownership. The age coverage of the survey ensures an appropriate sample size to analyse the effect of ageing on the demand for durable goods. The remaining sample size per wave varies between 7,700-9,700.

Twelve categories of household durable goods are covered by the ELSA. Each wave is asked if the household owns the durable good in question, if the household has purchased such an item in the last two years, and if yes, how much has the household spent on that item. Here I focus on the ownership and purchases of the durable items, rather than on the expenditures. Ownership and purchase dummies are less subject to measurement errors and are not distorted by the huge price variation of the available durable items. Instead of

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<sup>1</sup>The data was made available through the UK Data Archive (UKDA). ELSA was developed by a team of researchers based at the NatCen Social Research, University College London and the Institute for Fiscal Studies. The data was collected by NatCen Social Research. The funding is provided by the National Institute of Aging in the United States, and a consortium of UK government departments co-ordinated by the Office for National Statistics. The developers and funders of ELSA and the Archive do not bear any responsibility for the analyses or interpretations presented here.



analysing all categories of durable goods, I have selected three considerably different, widely-used items that I focus on throughout the paper. The first is television (TV) - a leisure good. The second durable good is the washing machine (WM) - a household appliance. The third durable good that I analyse is the computer (PC) - an item requiring a high level of technical knowledge. Appendix A provides graphical results for the other durable good categories.

Figure 1 shows the ownership of the three representative durable goods over age. This graph does not differentiate age and cohort effects. Moreover, it does not capture the influence of other individual characteristics. The graph shows three different age patterns for the ownership of the three categories of durable goods. The television ownership rate is already high by the age of 50 years, further increasing until age 90.<sup>2</sup> The ownership rate of washing machines is hump-shaped over the age of 50-90 years, with a decline after age 80. The ownership rate of computers declines steadily above age 50, although between the ages of 50-60 year the decline is moderate.

Since the ownership rates of televisions and washing machines are particularly high, one might wonder if the subgroup of individuals not owning the good is a very specific selected sample. In Table 1, I provide some descriptive evidence that, despite the owner and non-owner groups are different, these differences look reasonable and the average characteristics of the non-owner groups are not extraordinary. In section 4, I estimate the determinants of ownership and purchases by regression analysis, using an extended set of control variables.

The generation of the subjective survival probability indicator is also explained there.

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<sup>2</sup>As an anonymous reviewer pointed out, the eligibility for free TV license above age 75 could partly drive the increasing demand for TV at older ages. However, the graphical analysis does not indicate that the demand would start rising after the 75-year cut-off point. In addition, extending the regression analysis with a binary indicator of being aged above 75 years does not support the idea that a free TV licence would have a significant positive effect on TV ownership or purchases.

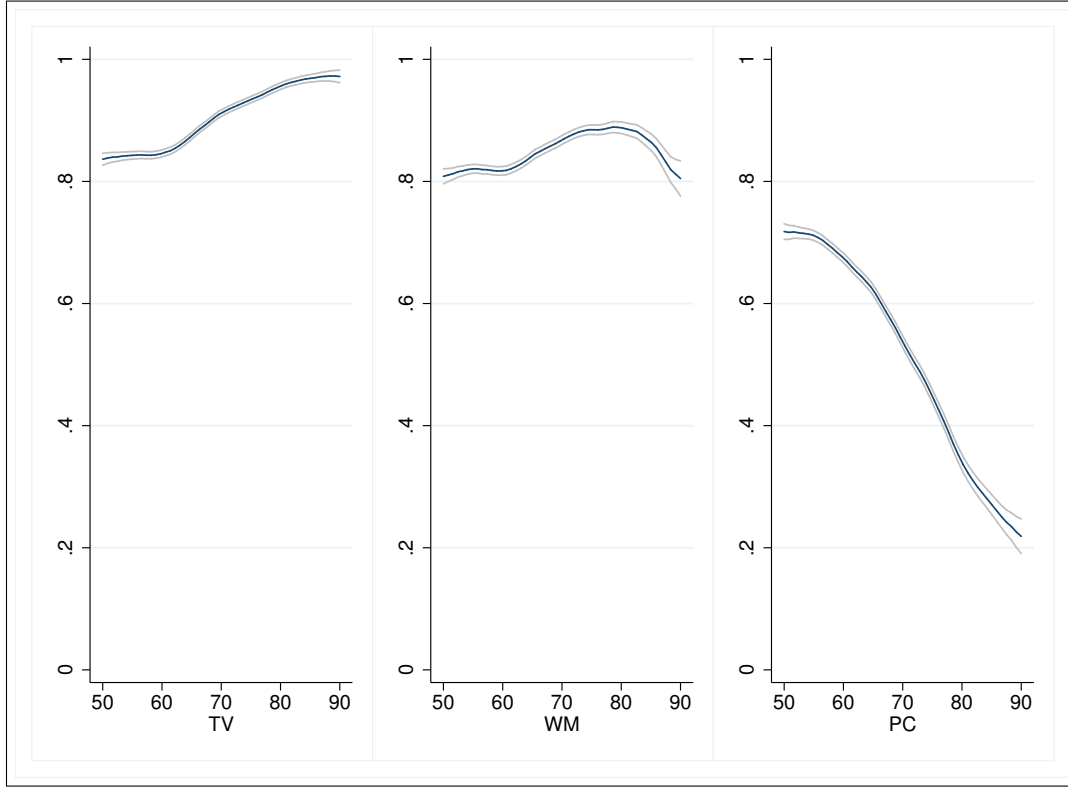


Figure 1: Durable good ownership ratio by age: local polynomial estimator and 95% confidence interval

		age	female	employed	retired	secondary education	higher education	10-year subjective survival prob
TV ownership								
no	mean	61.730	0.494	0.506	0.394	0.512	0.267	0.882
	std dev	7.688	0.500	0.500	0.489	0.500	0.443	0.175
yes	mean	65.773	0.546	0.343	0.537	0.449	0.162	0.766
	std dev	9.572	0.498	0.475	0.499	0.497	0.368	0.254
WM ownership								
no	mean	63.883	0.515	0.434	0.462	0.488	0.240	0.832
	std dev	9.278	0.500	0.496	0.499	0.500	0.427	0.227
yes	mean	65.566	0.545	0.349	0.531	0.451	0.162	0.770
	std dev	9.473	0.498	0.477	0.499	0.498	0.368	0.251
PC ownership								
no	mean	68.355	0.568	0.261	0.613	0.404	0.108	0.714
	std dev	9.967	0.495	0.439	0.487	0.491	0.310	0.284
yes	mean	63.116	0.521	0.435	0.454	0.494	0.221	0.826
	std dev	8.429	0.500	0.496	0.498	0.500	0.415	0.208

Table 1: Comparison of the owners and non-owners of the analysed durable goods

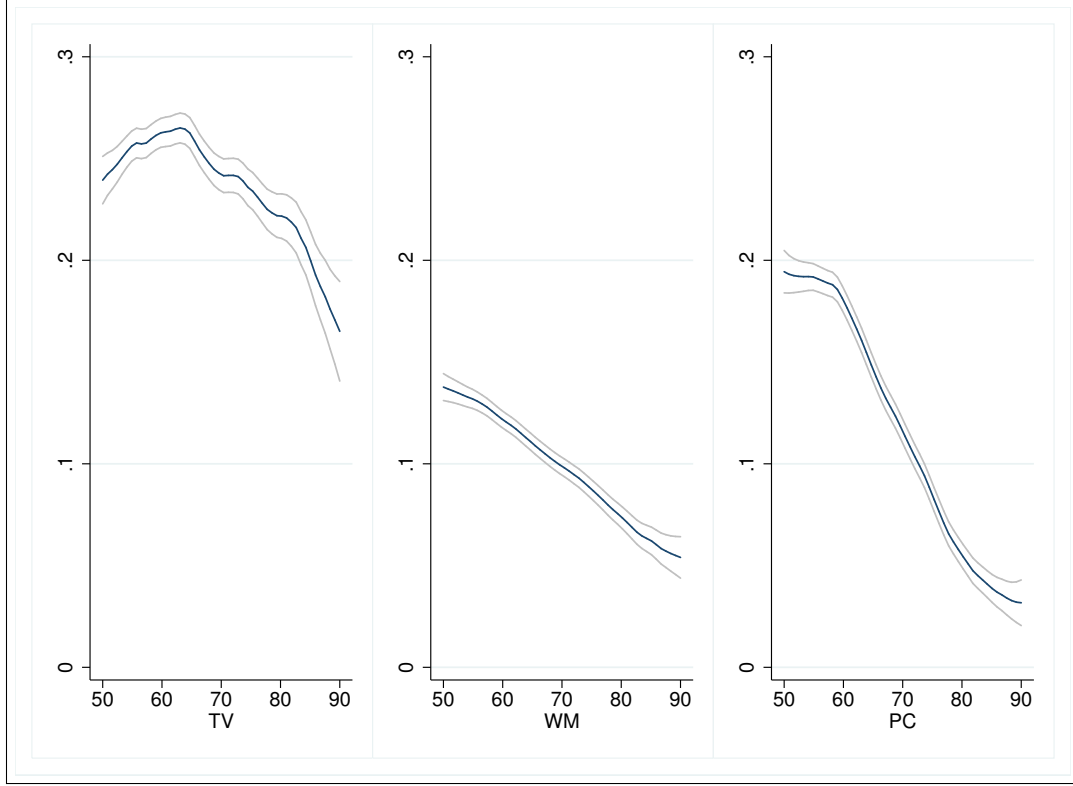


Figure 2: Fraction of respondents purchasing durable items the previous 2 years by age: local polynomial estimator and 95% confidence interval

As Figure 2 indicates, there is less variation in the purchase ratios throughout the analysed age interval than in ownership ratios. A slight hump-shaped pattern can be observed for television purchases with a peak around the age of 60-65 years. Computer and washing machine purchase probabilities tend to decline with age, the slope being slightly steeper for computers. The decreasing age pattern of purchases above age 50 is in line with Fernandez-Villaverde and Krueger (2007) and Browning et al. (2014), despite the fact that their analyses cannot reveal the different age pattern of television purchases. Moreover, they do not analyse the age pattern of durable ownership.

For the sake of comparison, in Figure 3 I present the age pattern of the average expenditures on the three representative durable goods. The expenditures are set to zero if no

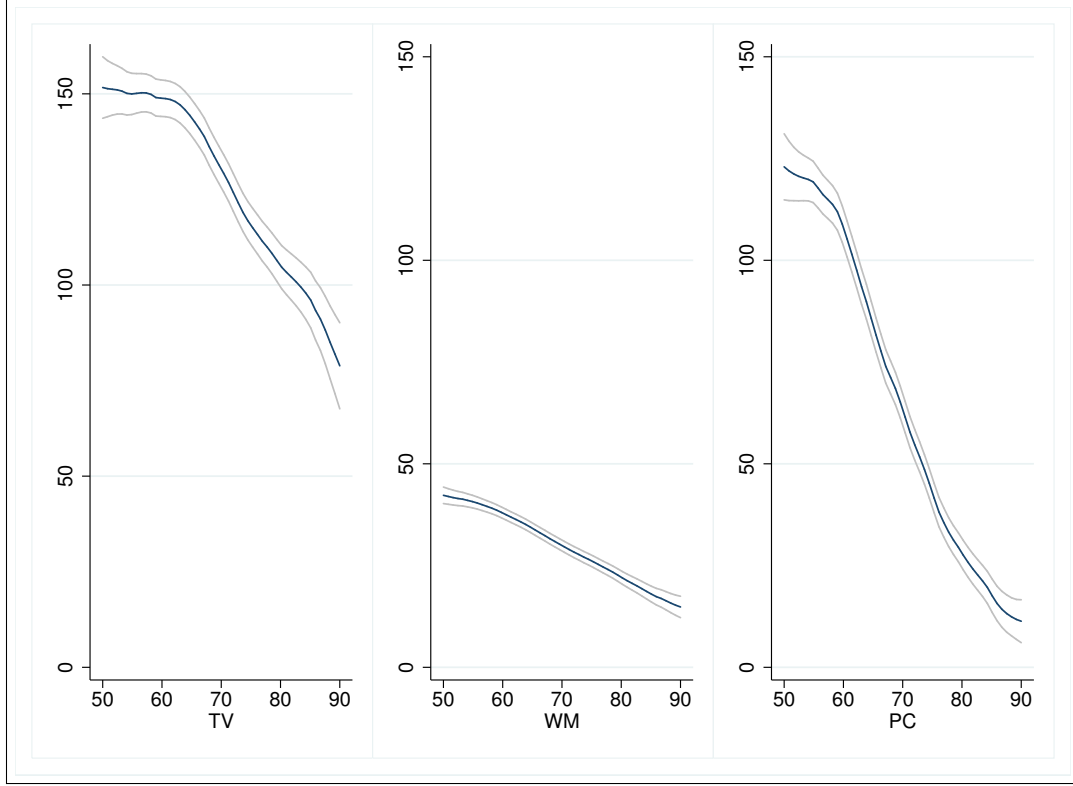


Figure 3: Expenditures on the durable items the previous 2 years by age, in GBP: local polynomial estimator and 95% confidence interval

purchase has taken place the previous 2 years.<sup>3</sup> As expected, the age pattern of the expenditures resembles the age pattern of the purchase ratios. The differences between the three categories reflect not only the different purchase ratios but also the differences in average price, which is the lowest for washing machine (313 GBP), the highest for computers (607 GBP) and the price of televisions lies in between (550 GBP).<sup>4</sup>

<sup>3</sup>I use only those answers where an exact value of expenditures is reported. I do not use bracket values. For all three durable goods, the exact value is missing only for around 5% of the observed purchases.

<sup>4</sup>The actual price of a durable item cannot be observed in the data. The "price" statistics reported here reflect the average reported expenditures for those who report positive expenditures. Thus, I assume that a respondent purchased a maximum of one item of the durable good within the two-year period.

## 4 Empirical evidence

In this section, I present the age pattern of the demand for durable goods, cleaning the demand from cohort and wave effects and from the effects of other individual characteristics. The aim is to analyse any residual effect of ageing and survival probability on the demand for durables. This empirical analysis is similar to Browning et al. (2014) and Fernandez-Villaverde and Krueger (2007), although I analyse different outcome variables. Thus, I focus on ownership and purchase indicators instead of expenditures and I analyse three narrow categories of durable goods, as described in section 3.

The relation of the ownership and purchase probabilities to individual characteristics is presented in Table 2. The average marginal effects presented are based on pooled probit models. I check them for age (using age dummies), time (wave) to capture aggregate price shocks or technical innovations and for cohorts (10-year birth intervals) to capture technical knowledge or cohort-specific preferences. The use of 10-year intervals to capture cohort effects is a simple but intuitive way to get around the linear interdependency of time, age and cohorts. Since age equals time minus birth year (cohort), the model would not be identified if all three variables were continuous measures. This is a well-known identification problem in the literature (Heckman and Robb (1985), McKenzie (2006), among others), while the results can be sensitive to the specification choice. Strong age effects are to be expected due to changing preferences with age, while time effects are important (and indeed statistically significant) because of price and other aggregate effects. Hence, I assume here that the knowledge or preferences captured by the cohort effects do not change continuously with time. With this specification, the estimated age effect shows the effect of age relative to the

base age (age 50), within a given cohort at a given year. The main drawback of this empirical approach is that some of the estimated age effects might, in fact, be cohort effects within the 10-year cohort groups. The other explanatory variables included are gender, education level, the quintiles of net financial wealth and equivalised income, indicators of employment and marital status, existence of children, household size, living area (government office regions), whether the respondent reports any difficulties with the activities of daily living (ADL) and instrumental activities of daily living (IADL), and finally, an indicator of subjective survival probability, which is based on a question asking about the chances of living until a target age, where the target age is around 10 years higher than the age of the respondent.<sup>5</sup> Since age and cohort are controlled for, the estimated effect of subjective survival probability captures the effect of the deviation of the subjective expectations from the statistical (life-table) probabilities.

As for ownership, the estimates reveal that a higher socioeconomic status increases the probability of computer ownership, while decreasing the probability of television ownership. The estimated marginal effects for washing machine ownership tend to be in the middle of the results for television and computer ownership. As for purchases, there are more similarities

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<sup>5</sup>Here I generate the 10-year subjective survival probability measure following the hazard scaling approach of Gan et al. (2005). First, I calculate the individual specific index of pessimism ( $\eta$ ) which is the ratio between the logarithm of the reported survival probability ( $s$ ) and the life table survival probability ( $S$ ) from the current age ( $t$ ) to the target age ( $t + a$ ):

$$\eta_i = \frac{\ln s_{it}^{t+a}}{\ln S_t^{t+a}}.$$

I will use the gender specific period life table for year 2004-2006 as provided by the Office for National Statistics (2014). To avoid missing values due to the logarithmic function, if  $s = 0$  then I replace the reported zero probability with 1% survival probability. The 10-year subjective survival probability is then calculated as

$$s_{it}^{t+10} = (S_t^{t+10})^{\eta_i}.$$

	Ownership			Purchase		
	TV	WM	PC	TV	WM	PC
female	0.0129*** [0.00397]	0.00986** [0.00498]	-0.0119* [0.00708]	-0.0131*** [0.00429]	-0.00225 [0.00312]	-0.0134*** [0.00359]
net fin wealth, 2nd quintile	0.00237 [0.00606]	0.00305 [0.00745]	-0.0217** [0.00971]	0.0222*** [0.00748]	0.000482 [0.00575]	-0.00397 [0.00613]
net fin wealth, 3rd quintile	-0.000788 [0.00610]	0.00756 [0.00741]	0.00572 [0.00979]	0.0284*** [0.00727]	0.00162 [0.00543]	0.00326 [0.00594]
net fin wealth, 4th quintile	-0.00935 [0.00625]	-0.00170 [0.00753]	0.0254** [0.0100]	0.0511*** [0.00730]	0.000287 [0.00539]	0.0222*** [0.00603]
net fin wealth, 5th quintile	-0.00996 [0.00632]	0.00857 [0.00762]	0.0491*** [0.0106]	0.0444*** [0.00757]	-0.00494 [0.00551]	0.0385*** [0.00623]
income, 2nd quintile	0.00596 [0.00525]	0.0172*** [0.00663]	0.0456*** [0.00920]	0.0203*** [0.00712]	0.00245 [0.00511]	0.0212*** [0.00583]
income, 3rd quintile	-0.00716 [0.00519]	0.00206 [0.00677]	0.0827*** [0.00962]	0.0341*** [0.00706]	0.00686 [0.00500]	0.0331*** [0.00573]
income, 4th quintile	-0.0329*** [0.00563]	-0.0210*** [0.00702]	0.100*** [0.00983]	0.0436*** [0.00718]	0.0143*** [0.00514]	0.0486*** [0.00571]
income, 5th quintile	-0.0647*** [0.00617]	-0.0556*** [0.00764]	0.0908*** [0.0104]	0.0589*** [0.00760]	0.0221*** [0.00557]	0.0561*** [0.00597]
employed	0.0167*** [0.00612]	0.0132* [0.00759]	-0.00788 [0.0103]	0.00563 [0.00787]	0.00928* [0.00560]	0.000981 [0.00640]
retired	0.00526 [0.00585]	0.00204 [0.00690]	6.69e-05 [0.00922]	0.00885 [0.00737]	0.00998* [0.00542]	0.000169 [0.00622]
married	0.00248 [0.00453]	0.0243*** [0.00565]	0.0377*** [0.00802]	0.00960* [0.00522]	0.00403 [0.00383]	0.000670 [0.00428]
widow	0.0280*** [0.00781]	-0.00144 [0.00773]	0.0112 [0.0101]	-0.0128 [0.00786]	0.00673 [0.00582]	-0.0129* [0.00678]
has child	-0.0271*** [0.00648]	0.00411 [0.00778]	0.0179* [0.0101]	0.00278 [0.00649]	0.0176*** [0.00493]	-0.00501 [0.00525]
household size	-0.0240*** [0.00230]	-0.0173*** [0.00286]	0.0500*** [0.00461]	0.0186*** [0.00296]	0.0154*** [0.00204]	0.0193*** [0.00231]
secondary edu	-0.0280*** [0.00551]	-0.0271*** [0.00642]	0.132*** [0.00832]	-0.0150*** [0.00539]	-0.00471 [0.00395]	0.0315*** [0.00497]
higher edu	-0.0381*** [0.00659]	-0.0462*** [0.00800]	0.207*** [0.0110]	-0.0385*** [0.00701]	-0.0120** [0.00519]	0.0582*** [0.00587]
other edu	-0.0152** [0.00739]	-0.0151* [0.00869]	0.121*** [0.0121]	-0.00862 [0.00769]	0.00443 [0.00550]	0.0361*** [0.00688]
10-yr survival	-0.00879 [0.0115]	-0.0119 [0.0122]	0.0618*** [0.0154]	0.00349 [0.0116]	-0.00526 [0.00888]	0.0275** [0.0111]
proability (0 to 1)	0.0123** [0.00539]	0.00850 [0.00628]	0.00636 [0.00833]	0.00177 [0.00644]	0.000579 [0.00479]	0.000683 [0.00565]
IADL	0.00325 [0.00544]	0.00732 [0.00647]	-0.0265*** [0.00816]	0.0124* [0.00661]	0.00396 [0.00498]	0.000716 [0.00579]
Age dummies	Yes	Yes	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes	Yes	Yes
Wave dummies	Yes	Yes	Yes	Yes	Yes	Yes
10-yr cohort dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	43,055	43,055	43,055	42,392	42,392	42,392

Standard errors in brackets, clustered at individual level, \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Table 2: Average marginal effects based on probit models of durable goods ownership and purchase

between the three durable goods: being female has a negative effect, good financial circumstances, while being married and household size have a positive effect. Both secondary and higher education have a positive effect only on the probability of buying a computer. Higher

subjective survival probability has a positive effect on the probability of owning and buying a computer, *ceteris paribus*. At the same time, it has a weakly significant negative effect on the ownership probability of washing machine. The opposite sign of the marginal effects on ownership and purchases does not necessarily imply a contradiction as ownership can result from purchases before the observation period or also from gifts. Replacing a durable good implies purchases while keeping ownership unchanged. In the model of section 5, the relationship between ownership and purchases will be captured in a simplified way. Due to depreciation, durable ownership can remain unchanged after a 10-year period but only if a replacement is made.

The figures 4 and 5 show the estimated marginal effects of the age dummies, conditional on individual characteristics, time, region and 10-year cohort effects.

The partial effect of age on the probability of durable ownership (Figure 4) is different from the total age effect (Figure 1). After eliminating the cohort and time effects and the effects of other individual characteristics, age has a smaller residual effect on durable ownership than the simple descriptive figures suggest. This is particularly true for computer ownership, although a similar effect holds for durable purchases (comparing Figures 2 and 5). We can observe some statistically significant positive age effects at the oldest ages in the case of television ownership. Moreover, there is a statistically significant negative age effect around age 60-70 on the ownership of washing machines and above around age 55 on computers. Above age 50 we can observe a U-shaped pattern in the age effect on washing machine ownership, but only a small part of these relations is statistically significant. Overall, the age pattern of washing machine ownership is in-between the pattern of television and computer ownership.



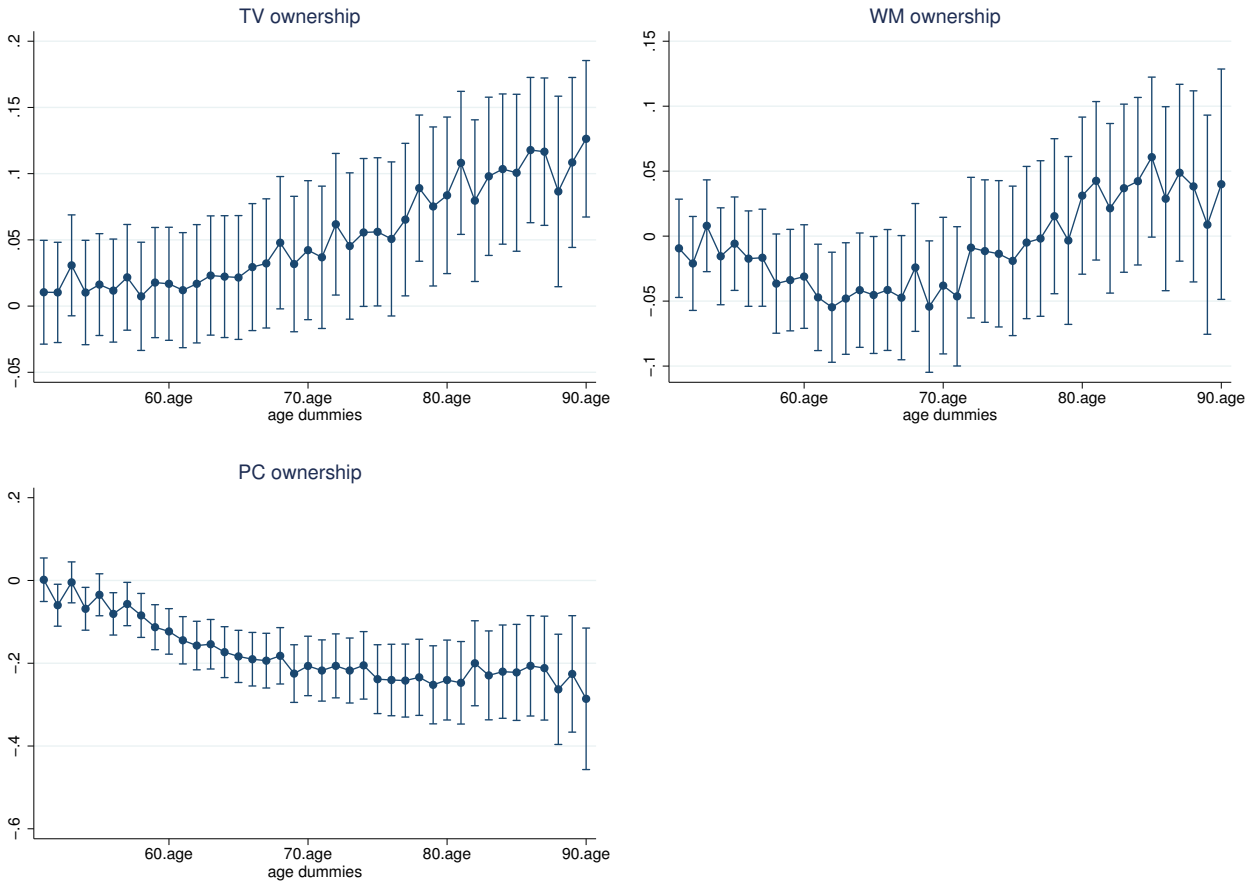


Figure 4: Average marginal effect and 95% confidence interval of age on durable good ownership

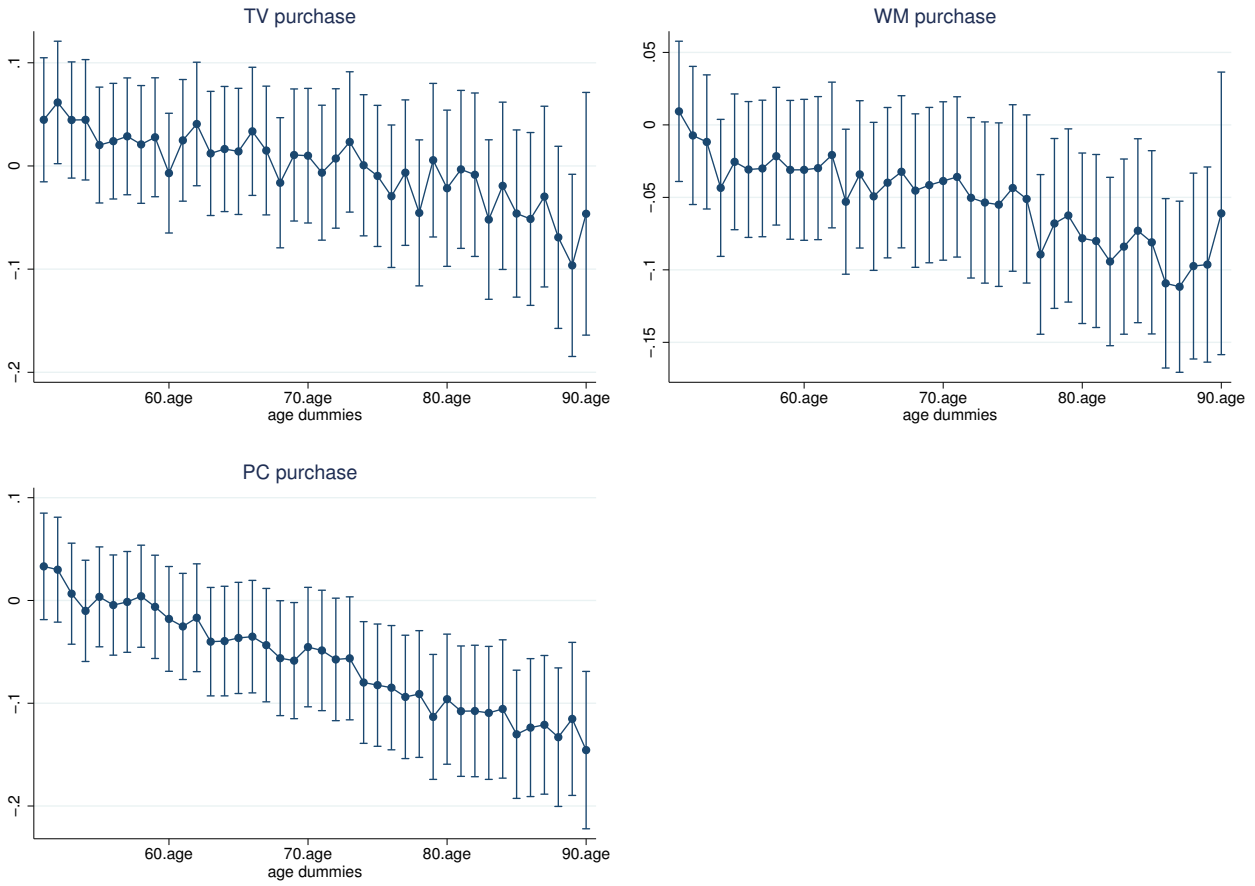


Figure 5: Average marginal effect and 95% confidence interval of age on durable good purchases

The partial effect of age on the probability of purchasing a durable good (Figure 5) is mostly statistically insignificant, although above age 70 we can see a negative age effect on the purchases of all three goods. Statistically, the strongest effect of age on durable good purchases is the negative effect of older ages on the probability of buying a computer. The age pattern of residual durable purchases is different from the results of Browning et al. (2014), who find a positively sloped age profile of durable expenditures for older ages once the cohort effects are taken into account. Differences in both the empirical specification and the data used can then contribute to the differing findings.

Overall, Figures 4 and 5 indicate that the individual observable characteristics and time effects can explain most of the age variation of durables ownership and purchases. The remaining age variation is relatively small, the strongest age effects can be observed for television (positive effects of higher ages) and computer ownership and purchases (negative effects of higher ages).

In turn, reduced form estimation techniques cannot reveal the underlying mechanisms that shape the age profiles of durable ownership and purchases, as presented in Figures 1 and 2. Therefore, in the next part of the paper I analyse the demand for durable goods in the framework of a life-cycle model.

## 5 Life-cycle model

### 5.1 Baseline model specification

Here I derive a discrete time life-cycle model in which utility depends on durable good ownership, non-durable consumption and health, and in which lifetime is uncertain. I only consider the utility maximisation problem of the individual, while the supply of goods is exogenous. This is a neoclassical model with no transaction costs. The aim of the modelling exercise is to obtain an understanding of the influencing mechanisms of age and survival probability on the demand for durable goods. I aim for simplicity and transparency but at the expense of it being possible to exactly match the model with the data. The model can only be solved numerically. In Appendix B I present a simpler 2-period model which has an analytical solution.

The benchmark model is specified as follows. There is one type of durable good. Individuals have maximum 50 years of remaining lifetime. They maximise their expected lifetime utility with decision variables of non-durable consumption and investment into a durable good. However, to keep the numerical solution of the model tractable, I assume that a decision on the investment into the durable good and on non-durable consumption is only made every 10 years. In the years when no decision is made on investment into the durable good (i.e. years 1-9, 11-19, etc), non-durable consumption equals income.<sup>6</sup> The maximisation

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<sup>6</sup>While the 10-year frequency of decisions might seem too restrictive, it might be reasonable for the population analysed. For older generations, it is less likely they will replace the durable goods unless a more advanced version is available. Owing to attrition and access to only 6 waves of the data, it is impossible to determine the frequency of purchases empirically. Between 10-25% of the respondents buy the analysed durable goods each wave (i.e. every two years). This trend may be in line with an average of 10-year frequency of purchase decisions. The depreciation guide of United Policyholders (2016) indicates 12 useful years of colour televisions, 8 useful years of automatic washers and 4 useful years of personal computers. The simulations demonstrate how people will decide if they can gain access to the durable good only every 10 years. Simulating the model by assuming more frequent decisions is also restricted by computational time.

problem is:

$$\max \sum_{t=1}^5 \delta^{10t} [s_{10t+50} (H_{10t+50}) u (C_{10t+50}, D_{10t+50}, H_{10t+50}|t) + (1 - s_{10t+50} (H_{10t+50})) v (W_{10t+50})], \quad (1)$$

where  $t$  denotes decades,  $C$  is non-durable consumption,  $D$  is the ownership of the durable good (0 or 1),  $H$  is health,  $W$  is wealth,  $\delta$  is the discount factor, and  $s_\tau$  is the probability of survival to age  $\tau$ , conditional on survival to age 50. The function  $u(.)$  is the current utility of consumption, durable good ownership and health, function  $v(.)$  is the utility of bequests. Durable good ownership increases utility due to the consumption service flow provided by the durable good. The maximisation is subject to the following conditions:

$$H_{10t} = H_{10(t-1)}\xi^{10} \quad (2)$$

$$W_{10t} = R^{10}W_{10(t-1)} - C_{10t} - pD_{10t} + Y_{10t} \quad (3)$$

$$C_{10t} \geq 0, W_{10t} \geq 0 \quad (4)$$

While variable  $D$  indicates the ownership of the durable good, it is assumed that by the end of each 10-year period the durable good breaks down with probability one and needs to be replaced if the decision-maker wishes to continue owning a durable good. According to equation (2), health is deterministic, depreciating with an annual rate of  $\xi$ . This is a simple way to capture that health tends to decline with age. Equation (3) specifies the dynamics of wealth, where  $R$  is one plus the annual interest rate,  $p$  is the price of the durable good (non-durable consumption is the numeraire) and  $Y$  is annual income. Income is assumed to be constant in the baseline specification, but it is allowed to drop after retirement under

the simulations of section 6. There is no credit in this model, entailing that wealth cannot be negative. I neglect income uncertainty and the decreasing trend in the relative prices of durable goods (as reported by Browning et al. (2014)). These assumptions are made to keep the model as simple as possible and to allow me to focus on the effect of ageing through survival probability, health and changing preferences.

The utility function is specified as:

$$u(C_{10t}, D_{10t}, H_{10t}|t) = \frac{f(C_{10t}, D_{10t}, H_{10t}|t)^{1-\gamma}}{1-\gamma}, \text{ where} \quad (5a)$$

$$f(C_{10t}, D_{10t}, H_{10t}|t) = \left[ 1 + \alpha_{10t} C_{10t}^{\frac{\phi-1}{\phi}} + (1 - \alpha_{10t}) D_{10t} \right]^{\frac{\phi}{1-\phi}} + \eta H_{10t}, \quad (5b)$$

$$\alpha_{10t} = \max(0, \min(1, \alpha_1 + \alpha_2 H_{10t} + \alpha_3 10t + 0.1\epsilon)). \quad (5c)$$

Parameter  $\gamma$  captures the relative risk aversion, and  $\phi$  the elasticity of substitution. The utility function of Fernandez-Villaverde and Krueger (2011) is similar, although they do not include health and use constant  $\alpha$ . I allow the utility weight of the non-durable and durable goods to depend on health and age (captured by  $t$ ), and on a random element  $\epsilon$ , which is assumed to follow standard normal distribution. In an extension of the model in Appendix C, I also allow the utility weight to depend on retirement status. In the baseline model, I assume that the utility weight of non-durable consumption increases with health whereas that of the durable good decreases with it. This assumption is based on the consideration that, with deteriorating health, people tend to spend more time at home thus attaching higher utility to the durable goods. I check the sensitivity of the results to this assumption in section 5.2.2. Apart from this multiplicative effect, health also has a direct effect on

utility through the additional  $\eta H$  term. This specification is similar to the one used by Finkelstein et al. (2013). The utility of bequests has the same parameter of risk aversion:

$$v(W_{10t}) = \beta \frac{W_{10t}^{1-\gamma}}{1-\gamma}. \quad (6)$$

$\beta$  is an indicator of the strength of bequest motives. A similar specification is used e.g. by Cocco et al. (2005). The probability of survival conditional on living up to age 50 is defined based on a modified Gompertz-Makeham law.<sup>7</sup> The modification compared to the standard Gompertz-Makeham law is that health is allowed to influence the baseline mortality:

$$s_{10t+50}(H_{10t+50}) = \frac{\exp \left[ -\frac{\omega_1 - \omega_2(H_{10t+50} - 0.5)}{\omega_3} (\exp(\omega_3(10t + 50) - 1) - \omega_0(10t + 50)) \right]}{\exp \left[ -\frac{\omega_1 - \omega_2(H_{50} - 0.5)}{\omega_3} (\exp(50\omega_3 - 1) - 50\omega_0) \right]}. \quad (7)$$

Table 3 presents the parameter values I use in the baseline specification. If possible, I use standard parameter values from the literature.

Table 4 shows the solution of the baseline specification.<sup>8</sup> At this stage my aim is only to present a baseline solution, as further analysis and reference to the three representative durable goods are provided in section 5.2.3. The model is not calibrated to match the observed age-pattern of durable good ownership and purchases quantitatively. Instead, the aim is to illustrate the model's implications using reasonable parameter values. The model's solutions can still be compared to the observed age-pattern of durable good ownership.

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<sup>7</sup>For details on the Gompertz-Makeham law and other widely used mortality models, see e.g. Pletcher et al. (2000).

<sup>8</sup>The model is solved numerically with the GAUSS 13 software. The solution procedure is the following. A random  $\epsilon$  is drawn. Conditional on this  $\epsilon$ , the optimal non-durable consumption values are found for each possible combinations of the 0/1 values of the durable good ownership. As the model is solved for 5 periods, there are  $2^5 = 32$  such combinations. Based on these solutions, I define the optimal set of durable good ownership. This process is repeated for 50 different values of  $\epsilon$ .

	Value	Remarks
$\delta$	0.9375	from Fernandez-Villaverde and Krueger (2011)
$H_{50} (*)$	1	health is measured on the 0-1 scale
$\xi$	0.955	chosen to $H_{100} = 0.1$
$R$	1.04	from Fernandez-Villaverde and Krueger (2011)
$p$	500	price of an average durable item (in GBP, based on ELSA statistics on expenditures)
$Y (*)$	3500	annual constant income to be spent on non-durable and durable goods (in GBP, based on expenditure statistics)
$W_{50}$	3500	value selected to equal one year's income
$\gamma$	2	from Fernandez-Villaverde and Krueger (2011)
$\phi$	1.167	from Ogaki and Reinhart (1998)
$\alpha_1 (*)$	0.81	from Fernandez-Villaverde and Krueger (2011)
$\alpha_2 (*)$	0.05	ad hoc, to allow utility weight of durables to decrease with health
$\alpha_3 (*)$	0	utility weight of durables not affected by age
$\eta (*)$	1	ad hoc, to capture direct utility from health
$\beta (*)$	0.1	ad hoc, to allow weak but not negligible bequest motives
$\omega_0$	$5 \cdot 10^{-4}$	similar values in Strulik and Vollmer (2013)
$\omega_1 (*)$	$3.36 \cdot 10^{-5}$	similar values for England and Wales in Strulik and Vollmer (2013)
$\omega_2$	$\omega_1/3$	ad hoc, to allow health to decrease baseline mortality
$\omega_3 (*)$	0.095	similar values for England and Wales in Strulik and Vollmer (2013)
(*): parameter values to be varied in the simulations of section 5.2 and Appendix C		

Table 3: Baseline parameter values

The baseline model implies considerable investments in the durable goods at ages 60-90, but the ownership ratio is much lower around the end of the possible lifetime. The high fraction of individuals owning the durable good up to the age of 90 years resembles the observed age patterns of television and washing machine ownership (Figure 1).

Extending the model with 5-year frequency of purchase decisions does not qualitatively change the implications of the baseline specification. Under this extension, the fraction of individuals owning the durable good is above 75% up to age 85. It then quickly decreases to 42, 8, and 0% at age 90, 95, and 100, respectively. To save computational time, in the following section, I base the results on the assumption of 10-year decision frequency.



Age	Baseline model solution
60	0.92
70	0.84
80	0.86
90	0.90
100	0.28

Table 4: Baseline model solution: fraction of individuals owning the durable good

## 5.2 Simulations

In the following, I analyse the effects of discounting, health, longevity and preference parameters on the age pattern of durable good ownership. Appendix C presents further simulation results related to the influence of bequest motives and retirement.

### 5.2.1 Partial effect of discounting

Using the model of section 5.1, I will analyse the partial effect of discounting on the demand for durables. The results presented in Table 4 show the total effect of ageing, including the discounting of later utilities, deteriorating health and decreasing survival probability.

To arrive at the partial effect of discounting, I solve the same optimisation problem as in section 5.1 with the difference that health is now constant ( $\xi=1$ ) and the probability of survival to any age equals the probability of survival to age 51 (at age 50). Hence, apart from a risk in one-year survival, there is no mortality risk in this specification. The age pattern of durable good ownership under this specification is solely due to the effect of discounting and the existence of small bequest motives. It is not due to health, survival probability or preferences changing with age.<sup>9</sup> The results are presented in Table 5. In conclusion, these

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<sup>9</sup>I keep bequest motives in this specification to ensure the optimisation process is feasible. Having no bequest motives would imply corner solution at the last period.

results can be compared to the age effects estimated from the data and presented in Figure 4, which are cleaned from the effect of health, survival probability and other observable characteristics.

If, in addition to the elimination of the effect of health and uncertain survival, the discount factor is set to one ( $\delta=1$ ), then as Table 5 shows, there is no longer a drop in the ownership ratio at the oldest ages. Hence, the age pattern of the demand for the durable good is roughly flat.

Age	$\delta=0.9375$	$\delta=1$
60	0.80	0.84
70	0.82	0.78
80	0.82	0.84
90	0.82	0.86
100	0.68	0.84

Table 5: Partial effect of discounting: fraction of individuals owning the durable good

The simulated effect of ageing is smaller if health and survival probability are kept constant. This is in line with the empirical results that the partial effect of age on durable good ownership (Figure 4) is smaller than the raw age differences in ownership (Figure 1). The simulated effect of discounting on ownership is flat up to the oldest possible age when it declines, but to a lesser extent than under the baseline specification. Thus, the big drop in ownership at the oldest ages under the baseline is due to declining health and small survival probability up to those ages. Assuming constant health and no risk of mortality, it is optimal to own the durable good at the oldest ages with the highest probability.

### 5.2.2 Influence of health

Next, I will analyse the sensitivity of the results to the health-related parameters. I modify the baseline set of parameters in a stepwise fashion and the results are presented in Table 6. As the first step, the initial level of health is reduced to 0.5, instead of 1. This modification implies that the fraction of individuals possessing the durable good increases slightly at ages 70 and 80, but at the oldest ages the fraction is somewhat lower than under the baseline specification (with better initial health). This difference is reasonable because, with worse health the survival probabilities are also lower, implying that the expected utility derived from the durable good at the oldest ages is also lower. Setting the direct effect of health on utility to zero ( $\eta = 0$ ) implies that a slightly higher fraction of individuals own the durable good at ages 70 and 80.

One reason for this change can be that under this modified specification the durable good (and the non-durable good, as well) has a stronger relative impact on the utility levels than before, implying higher demand. Setting  $\alpha_2 = 0$  has even bigger effects. If the utility weight of the durable good is constant, instead of increasing with declining health then the fraction of individuals possessing the durable good is roughly constant up to the oldest ages, then there is no longer a peak around the age of 80 as seen in the previous specification.

Age	$\alpha_2=0.05, \eta=1, H_{50}=0.5$	$\alpha_2=0.05, \eta=0, H_{50}=0.5$	$\alpha_2=0, \eta=0, H_{50}=0.5$
60	0.92	0.92	0.92
70	0.86	0.88	0.90
80	0.92	0.98	0.90
90	0.90	0.88	0.90
100	0.22	0.18	0.30

Table 6: The influence of health and health related parameters: fraction of individuals owning the durable good

### 5.2.3 Effect of longevity on two types of durable goods

The life-cycle model can also be used to analyse the effect of changing longevity on the demand for durable goods. Due to inherent endogeneity in measures of subjective longevity, this effect is difficult to identify empirically. I analyse the effect on two types of durable goods, a "television-type" and a "computer-type" good. The use of the two goods requires different levels of technical knowledge and hence different health levels. Therefore, the age effects are expected to be different, as the figures of sections 3 and 4 also indicate. I then modify the baseline model so as to represent the demand for these two types of goods, but as a simplification, I still neglect the possible interactions between the demand for the different durable items.

I simulate the effect of increasing longevity of a similar magnitude as the longevity increased between the first and last quarter of the 20th century in Great Britain. The historical parameters of the survival model are taken from Strulik and Vollmer (2013). I run simulations with the original (current) parameters, and the historical ones, where  $\omega_1 = 2.35 \cdot 10^{-4}$  and  $\omega_3 = 0.0795$ . The original and the lower probabilities of survival, conditional on living up to age 50, are presented in Figure 6.

In the first simulation, I analyse the effect of increasing survival probability on the demand for a "television-type" good. The utility weight of this good increases with age and decreases with health. The assumption here is that with ageing and deteriorating health, more time is spent at home, which increases the utility derived from having a television at home. The

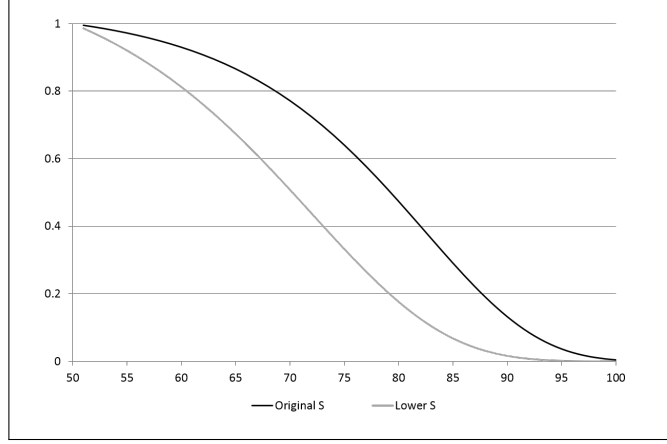


Figure 6: Survival probabilities conditional on living up to age 50

utility weight of the non-durable good is  $\alpha_t$ , while of the durable good it is  $1 - \alpha_t$  where

$$\alpha_{10t} = \max \left( 0, \min \left( 1, 0.8 + 0.15H_{10t}^2 - 2.25 \cdot 10^{-4} (10t)^2 + 0.1\epsilon \right) \right). \quad (8)$$

As before,  $t$  runs between 1 and 5, and  $\epsilon$  is a standard normal random variable. The parameters are selected in such a way that the average utility weight of the non-durables at age 60 is similar as before (equation 5c), which is around 0.82. It then decreases to around 0.24 by the end of the possible lifetime. The rest of the parameters are the same as under the baseline specification.

Table 7 shows the simulation results. Compared to the baseline results (Table 4), the probability of holding the durable good is higher at older ages; that is, it is 1 from age 70 on. The increasing probability of owning the durable good resembles the age-pattern of television ownership (Figure 1), although the observed ownership rate increases monotonically between ages 50 and 90. The simulations also show that higher chances of survival imply higher demand for the good at the oldest ages.

In the second simulation, I look at a "computer-type" good. The utility weight of this

type of durable good increases with health and decreases with age. The reasons for this assumption are that mental or physical health problems might limit the capabilities of older individuals to use computers (Pew Research Center (2014), Rosenberg et al. (2009)), while older people might be less capable to learn new and fast changing technologies. The utility weight of the non-durable good is now specified as

$$\alpha_{10t} = \max \left( 0, \min \left( 1, 0.835 - 0.1H_{10t}^2 + 0.9 \cdot 10^{-4} (10t)^2 + 0.1\epsilon \right) \right). \quad (9)$$

In this specification, at age 60  $\alpha$  has a slightly lower average value than in the baseline (around 0.8), where it approaches 1 at the oldest ages.

The simulation results are presented in the second part of Table 7. Compared to the baseline, it is optimal to hold the "computer-type" durable good with a higher probability around age 60; the demand for this type of durable good then drops. This age pattern is reasonable as the utility weight of the durable good is assumed to decrease steeply with age. Re-optimising the model with lower survival probabilities has negative effect on the ownership ratio, the influence of survival probability is bigger than on the "television-type" good. This effect is close to zero at the oldest ages. As the ownership ratio of the durable good at those ages was already close to zero, there is little scope for further decline. However, if together with increasing life expectancy the understanding of the "computer-type" good also increases at older ages (hence  $\alpha_t$  increases less with  $t$ ), then increasing longevity would imply even higher demand for the good at older ages.

It follows from this discussion that the effect of increasing longevity on the demand for durable goods is not trivial. The fraction of individuals owning the durable good at

Age	TV		PC	
	Original survival probability	Lower survival probability	Original survival probability	Lower survival probability
60	0.74	0.88	1.00	0.94
70	1.00	1.00	0.82	0.68
80	1.00	1.00	0.60	0.48
90	1.00	1.00	0.28	0.06
100	1.00	0.88	0.02	0.00

Table 7: Effect of longevity on the demand of "television-type" and "computer-type" durable goods: fraction of individuals owning the durable good

old ages becomes higher, but the magnitude of this increase strongly depends on how the preference parameters change with age. The effect of longevity at the oldest ages is smaller on such a good, which is more attractive to younger individuals mostly due to the required advanced technological knowledge. On the other hand, the effect of longevity at younger ages is smaller on goods for which the demand is so high that ownership is optimal even if the survival probabilities are lower.

## 6 Conclusions

In this paper, I analyse both empirically and theoretically how ageing is related to the demand for three representative types of non-housing durable goods; namely, televisions, washing machines and computers. The empirical analysis is based on ELSA, an English panel data set covering individuals aged 50 and above. Although durable good ownership and purchases can be related empirically to age, cohort and subjective survival probability, such an analysis cannot reveal the influencing mechanisms of ageing. Furthermore, ageing can be conceptualised in multiple ways: analysing the effect of approaching the end of possible lifetime, changing chances of survival and deteriorating health can all be considered

as aspects of the ageing process. These are then jointly reflected in the age gradient of durable good demand. The theoretical model and simulations presented have thus aimed to capture these complex relations in a simplified manner.

The age pattern of observed durable good ownership and purchases is considerably different from the age pattern once time and cohort effects and the influence of other individual characteristics are taken into account. The strongest residual relations can be seen for computer ownership and purchases, which are higher at younger ages and among people with higher subjective chances of survival.

The life-cycle model presented in the paper is novel in terms of capturing the binary nature of ownership decision and accounting for the substitutions with non-durable consumption, uncertain lifetime, the influence of health and bequest motives at the same time. The baseline solution of the model indicates that the durable good ownership rate drops at the oldest ages. Simulations indicate that when holding health and survival probability constant, the age pattern of durable good ownership is close to being flat. Higher chances of survival increase the ownership ratio of the durable items. However, the magnitude of the effects depends on the preference parameter assumptions. Hence, structural estimation of the preference parameters is hindered not only by data limitations, but also by the fact that a sufficiently realistic model of durable goods demand cannot be solved analytically.

Overall, descriptive empirical analysis suggests a hump-shaped age pattern of durable good ownership above the age of 50 years. The results of the theoretical model resemble this hump-shaped pattern if the effect of retirement is taken into account. This pattern is the result of complex relations, including cohort effects and changing preferences with age. Strong bequest motives might eliminate the hump-shaped pattern. Moreover, different types



of durable goods have different age gradients, as the utility derived from their possession varies differently with age. When considering the effect of ageing on durable goods demand, one should keep in mind that ageing has multiple aspects, including deteriorating health and changing consumption preferences. Goods that are leisure complements can increase well-being in old age groups, a trend which is suggested by the observed aged patterns of ownership rates. They can be rationalised with a theoretical model that allows for changing preference parameters.

The results of the paper suggest that increasing longevity raises the demand for durable goods at older ages, implying higher demand for such non-housing durable goods in an ageing society. This increasing demand might be partly offset by increasing the retirement age, especially in the case of such goods which have a higher use value if the available leisure time increases.

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# Appendix

## Appendix A: Results for other categories of durable goods

Below, I present empirical results for those types of durable goods that are not analysed in the main text. Here I only focus on ownership, as purchases decline with age for all the goods.

First, Figure 7 displays the observed aged pattern of ownership. Apart from fridge freezers/deep freezers and microwave ovens, ownership declines with age, at least starting from around age 70. Although some of the age patterns are steep, these are not as steep as are observed for computers. Many of these goods represent relatively new technologies (e.g. DVD players, online-digital televisions) and can be considered as "luxury" goods, thus the decreasing demand with age is not surprising. The different age patterns of freezers and microwave ovens are also reasonable along the same lines. These require little technical knowledge, as good physical or mental health are not prerequisites for their use and can be considered as essential electrical appliances.

Second, Figure 8 shows the partial effect of age on the ownership of the durable goods. These results are obtained in the same way as the results of Figure 4. Conditional on 10-year cohort, survey wave, region effects and individual characteristics, most of the marginal effects are statistically insignificant and quantitatively small. Some positive effects at the oldest ages can be observed on the ownership of freezers and microwave ovens, and negative on DVD players and online-digital TVs. These results suggest that in itself age has a moderate effect on the ownership probabilities of the non-housing durable goods, but the marginal effects of the highest ages tend to be negative on more technically advanced goods and positive on

goods that require little technical knowledge and are essential household items.

## Appendix B: Two period model

I present here the simplest possible two-period model, which is analytically solvable, but can still capture some of the mechanisms driving the results of section 5.1. As much as possible, this simplified model follows the logic and notation of the baseline model.

There are two periods. Utility depends on non-durable consumption and durable good ownership (which is 0 or 1). The durable good depreciates completely from period 1 to 2; thus it needs to be replaced if the decision maker wishes to own the good in the second period. The survival probability to the second period is  $s$ . There are no bequest motives and hence wealth is depleted in the second period. Unless otherwise stated, the notations are the same as in section 5.1.

The maximisation problem is as follows:

$$\max u(C_1, D_1) + \delta s u(C_2, D_2), \quad (10)$$

Subject to the following constraints:

$$C_2 = RW_1 + Y - pD_2, \quad (11)$$

$$W_1 = RW_0 + Y - pD_1 - C_1. \quad (12)$$

Initial wealth, income and survival probability  $(W_0, Y, s)$  are exogeneous here. To keep the model tractable, I also assume that the first period consumption  $(C_1)$  is exogenous -

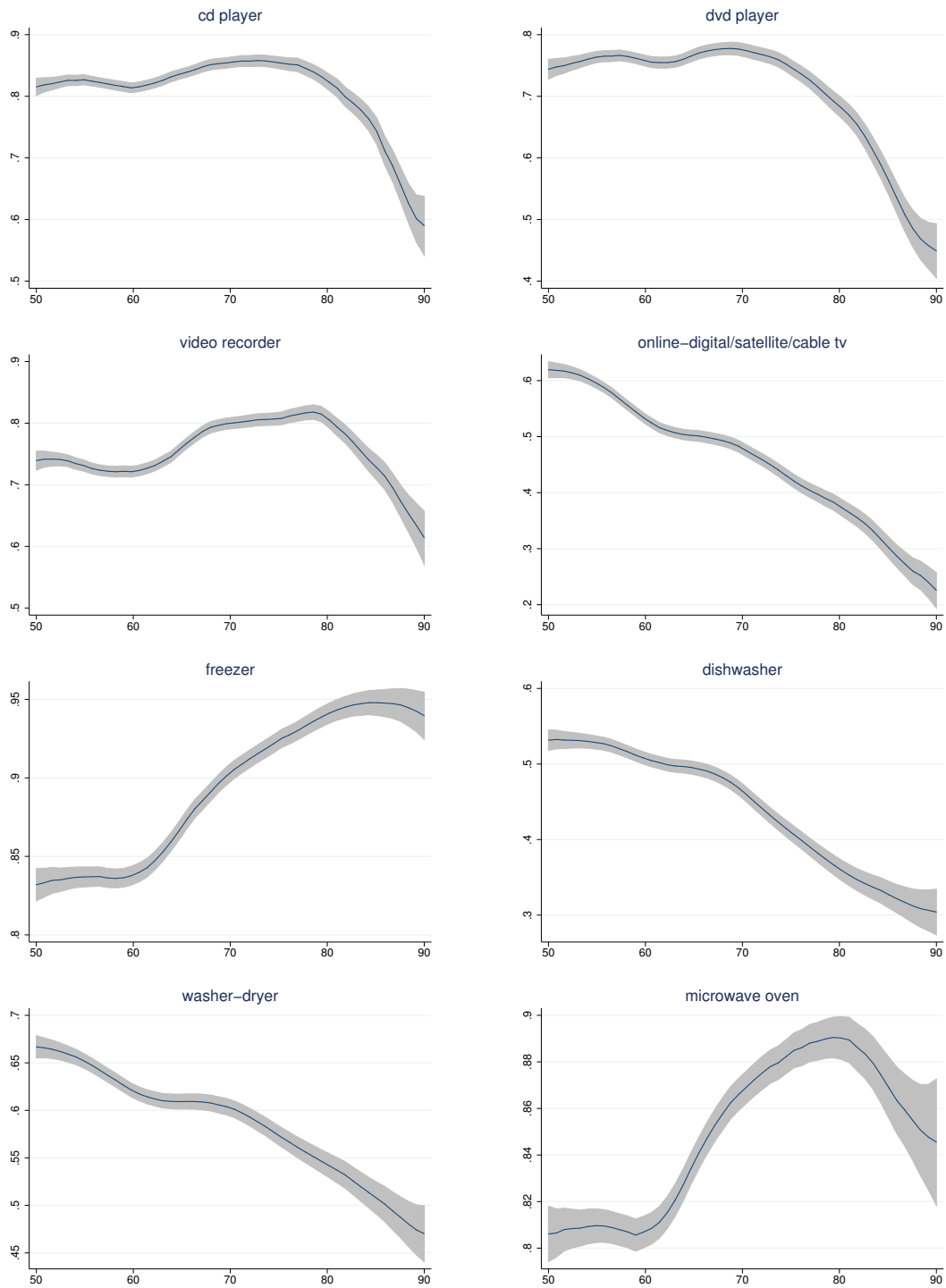


Figure 7: Durable good ownership ratio by age: local polynomial estimator and 95% confidence interval

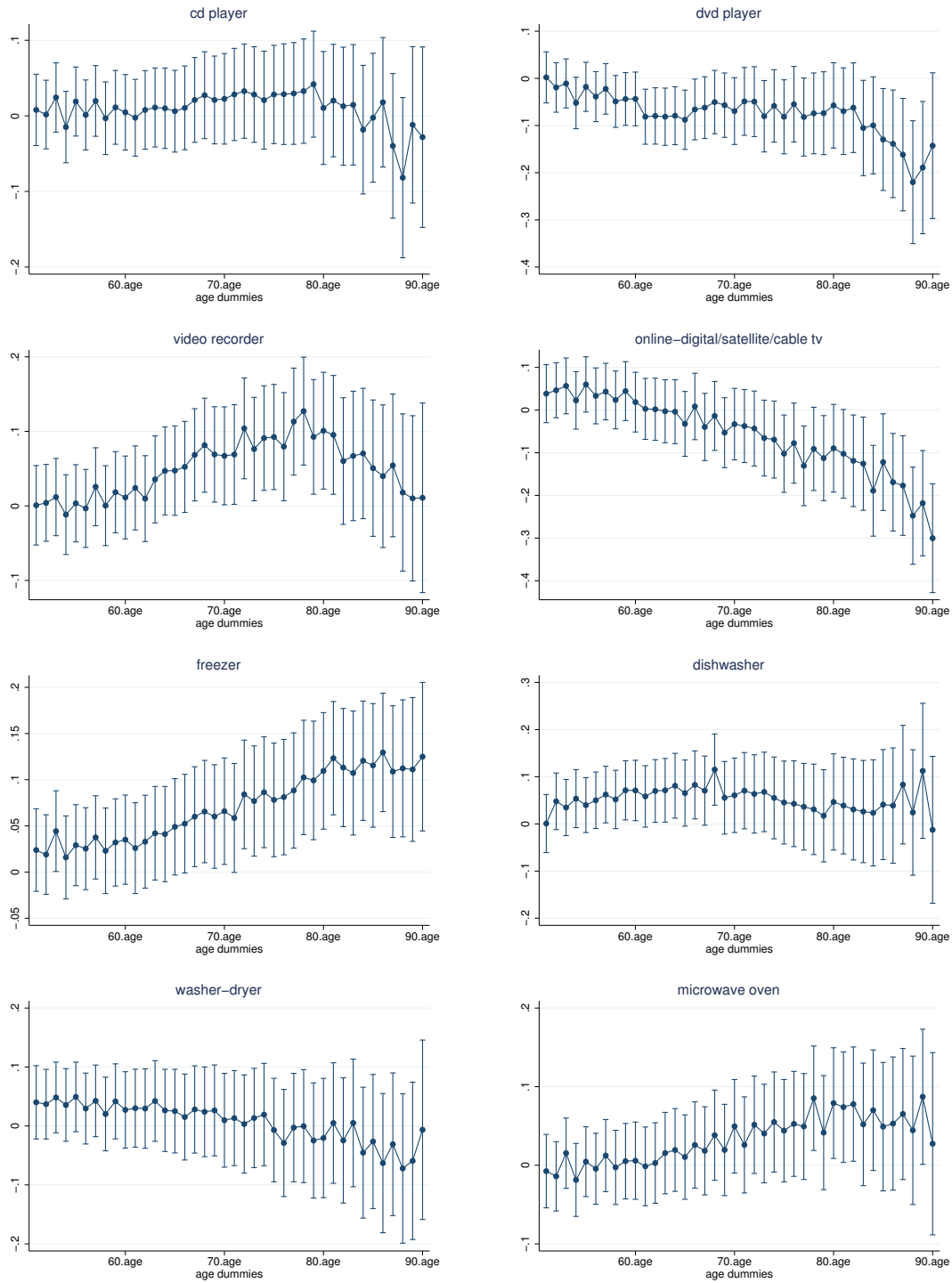


Figure 8: Average marginal effect and 95% confidence interval of age on durable good ownership



this can correspond to the usual value of non-durable consumption. With this assumption, there are only two decision variables:  $D_1$  and  $D_2$ . Utility is specified as a linear function of non-durable consumption and durable good ownership:

$$u(C, D) = (\beta_0 + \beta_1 I(t = 2))C + (1 - \beta_0 - \beta_1 I(t = 2))D, \quad (13)$$

where  $\beta_1$  parameter captures age effect, a positive value implying that the utility weight of the durable good decreases with age.

Due to the linearity and exogeneity assumptions, the optimisation simplifies to the comparison of four utility levels (normalised to the first utility level being equal to 0):

1.  $U(D_1 = 0, D_2 = 0) = 0$ .
2.  $U(D_1 = 1, D_2 = 0) = 1 - \beta_0 + \delta s(\beta_0 + \beta_1)(-Rp)$ .
3.  $U(D_1 = 0, D_2 = 1) = \delta s((\beta_0 + \beta_1)(-p) + (1 - \beta_0 - \beta_1))$ .
4.  $U(D_1 = 1, D_2 = 1) = 1 - \beta_0 + \delta s((\beta_0 + \beta_1)(-p - Rp) + (1 - \beta_0 - \beta_1))$ .

These results imply, among others, that  $D_1 = 0, D_2 = 1$  is more likely to be preferable over  $D_1 = 0, D_2 = 0$  and similarly,  $D_1 = 1, D_2 = 1$  over  $D_1 = 1, D_2 = 0$  if the price of the durable good is smaller, if the baseline utility weight of the non-durable good ( $\beta_0$ ) is smaller, and if the utility weight of the durable good increases with age ( $\beta_1 < 0$ ). Furthermore, increasing durable good ownership ( $D_1 = 0, D_2 = 1$ ) is more likely than decreasing ownership ( $D_1 = 1, D_2 = 0$ ) if the survival probability ( $s$ ) and discount factor ( $\delta$ ) are higher, and if  $\beta_0$  and  $\beta_1 < 0$  are smaller.

These implications of the two period model are in line with the simulation results of the multiple period, extended model.

## Appendix C: Further simulation results

### Appendix C1: Influence of bequest motives

The parameter capturing the strength of bequest motives was selected in the baseline specification in an ad hoc fashion. Therefore, it is necessary to understand how sensitive the model's predictions are to this parameter.

An important assumption throughout the paper is that durable goods are not bequeathable or have no value for the successors. Otherwise, the ownership ratio of durable goods would be higher, especially at the oldest ages. In the baseline specification the parameter capturing the strength of bequest motives was set to  $\beta = 0.1$ . Here, I first solve the optimisation problem with  $\beta = 1$  (strong bequest motives), then I solve the model with the original  $\beta$  parameter, but allowing the durable good to be bequeathable. The utility of bequests now equals

$$v(W_{10t}) = \beta \frac{(W_{10t} + pD_{10t})^{1-\gamma}}{1-\gamma}. \quad (14)$$

The results are displayed in Table 8. Under strong bequest motives the demand for the durable good is lower than under the baseline specification. This is reasonable, as the decision-maker wishes to decumulate her wealth to a lesser extent to ensure that she can leave bequest. This simulation indicates that the strength of the bequest motives has a relatively strong influence on the demand for the durable good.

If the durable good is bequeathable, then the probability of holding the durable good is

close to one at each period. This probability would be lower if, in equation (14), the nominal value of the durable good were to have a lower weight in the utility of bequest than the remaining financial wealth.

Age	Strong bequest motives ( $\beta = 1$ )	Bequeathable durable good ( $\beta = 0.1$ )
60	0.84	0.86
70	0.84	0.90
80	0.74	0.98
90	0.62	0.90
100	0.02	1.00

Table 8: The influence of bequest motives: fraction of individuals owning the durable good

## Appendix C2: Effect of retirement

The empirical results (Table 2) indicate no significant effect of retirement on the ownership of durable items, but a statistically stronger positive effect of around 1% on the probability of television and washing machine purchases. The estimates are insignificant if the transition into retirement is used as a regressor. Although no immediate effect of retirement can be observed, it is still possible that retirement influences the optimal ownership and purchases of durable goods over the life-cycle. To analyse this effect, I run simulations with changing income and changing preferences at retirement age.

I assume that the decision maker retires at age 65. First, I replace the constant income with an annual income value of 4,077 between ages 50-65, and 2,446 between ages 66-100. These income values were selected, such that the pension replacement rate is 60%, and the discounted sum of income is the same as under the baseline specification. Second, I assume not only that income drops at age 65, but also that the utility weight of the durable good increases at the same time. This assumption can be especially reasonable for leisure

goods (television-type durable goods). Under this specification,  $\alpha_1 = 0.9$  for ages 50-65, and  $\alpha_1 = 0.76$  for ages above 65 (the weighted average equals the baseline value of 0.81). Again, the model is solved with the assumption that investment decisions are only made every 10 years, while in the other years, consumption equals income. The simulation results are presented in Table 9.

Age	Income drops at retirement	Income drops and preferences change at retirement
60	0.86	0.56
70	0.88	0.64
80	0.92	0.98
90	0.78	0.90
100	0.20	0.30

Table 9: The influence of retirement: fraction of individuals owning the durable good

Compared to the baseline specification, a drop in income at age 65 implies higher ownership ratio at ages 70 and 80 than under the baseline. The demand for the durable good does not drop when income drops, which is in line with consumption smoothing. The slightly higher demand at ages 70 and 80 is reasonable. Although the present value of the income flow is the same as before, if lifetime uncertainty is taken into account, then the expected present value of the future income flow is higher here. The income level is higher until age 65 when the survival probability is high, while it is lower above age 65 when the chances of survival are also lower. The higher initial income, together with the non-negativity constraint on wealth, also enable higher expenditures.

If the utility weight of the durable good increases with retirement, then there is a peak in the durable ownership ratio around the age of 80. The increasing pattern of ownership above age 50 and below the age of 90 resembles the observed age pattern of television and washing machine ownership.